Transpiration of Water in Plants.

Thesis for the Degree

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by

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My object in this thesis is to determine, viz: 1st Through what part of the plant the water flows, 2nd Whether or not the leaves absorb water, 3d The pressure of Sap, 4th The amount of water given off by the leaves.

It can be proven in three ways that water does not flow through the bark. First I took a number of diffrent stems and put the cut ends in a solution of carmine and blue aniline, I found that neither the bark or pith were stained, and that the amount of stain increased from the pith outward until it reached the bark, the new tissue next to the bark, which is course, was always stained, while in the finer woody tissue only a few ducts were stained. 2nd Take trees before they bud out, girdle some of them and cut all the woody part out of the others, the latter bring

supported by a frame work," I found that the trees that were girdled bruded out and further a couple of trees that were girdled the year before bruded out also; but the tree which had the interior cut out bruded out also, this was due to the fact that there was still a little strip of wood about an inch wide and one twentieth of an inch thick around the circumference which had not been cut out, after that was severed the tree died with in a day. There is no doubt that this tree would never have bruded out if this strip of wood had been cut out in the first operation.

3d. By taking branches of trees, especially Maple and Box Elder, and placing blotting paper over the cut end then removing and observing closely, I found that the water came out through the woody part. These three prove conclusively that the water flows through the woody tissues and not through the bark or pith. In the Plate 7 fig 2 represents a tree which has been girdled. 7 fig 3, one with the interior removed, T. is a section of a Maple which was stained with carmine. the dots represent

the ducts which were stained red. Fig 8, is a section of a Willow which was stained with aniline blue, the shaded part next to the bark represents the tissue which was stained blue.

Leaves will not absorb water only when they lose a portion of their water of constitution, which is essential to their existance. They are able to replace the roots of plants for a considerable length of time throug the agency of absorption. I took several cuttings of Coleus, sealed the end of some of them and left the end of the others unsealed, then placed them in a can of water, "which are represented in the Plate by Figs. 5 and 6.", with the same number of leaves under water as above; At the end of eight weeks those which had their cut ends sealed up were still fresh and roots formed upon the stems, while the others began to wither and no roots were formed, others with just the ends immersed lived from 6 to 8 days before they began to wither. Leaves will also absorb solutions of Salts, such as Sulphate and Nitrate of Potassium; Chloride of Sodium and Nitrate of Ammonium.

These were disolved in distilled water and a drop placed on the leaves of several different kinds of plants and covered over with a small porcelain cover so that no evaporation could take place on the out side; as shown in the Plate, Fig. 4, in every instance the water was all absorbed and in some cases a residue was left upon the surface. When the solution was too strong the leaves were killed. By weakening the solution they were not injured and no residue left. The under side of the leaves were found to absorb more water and much quicker than the upper side, probably due to the fact that the under side has the greater number of Stomates to the square inch. These experiments prove that the leaves of plants are able to supply them selves with a portion of their saline constituents from the Ammonical salts formed in the air, and the Alkaline and earthy salts suspended there which are deposited on the surface of the leaves by rain and dew.

The rate of movement of water varies in different plants this is estimated by placing the ends of cuttings in an aqueous

solution of carmine, and leave them there for an hour or the time required, then divide the height which the wood was stained by the number of hours left in the solution. The following are the results from a few experiments. Viz:- Willow 10 inches an hour. Lilac 6 inches, Rasberry 8 inches, and Blackberry 6 inches. The coloring matter was carried up partly by Capellary attraction and partly from evaporation from the leaves. It was found that the wood could only be stained to a given height on account of the colloring matter being absorbed.

The fact that water is found on leaves may not always be caused by dew throught the change of temperature. It may be caused by interal pressure forcing out an extra amount of water which collects upon the surface. I took several branches which contained leaves and fastened them in the hose, which had a pressure of twenty pounds to the square inch, within the space of one minute drops of water could be seen comming out around the circumference, at the points where the

vins terminate and also at the nodes. Thus on the same principle water may be forced out by means of the roots and collect in drops at the base of the leaves.

Experiment with the pressure of sap as found in the grape vine. I took a two ounce bottle filled it about $\frac{2}{3}$ full of Mercury, closed it with a two perforated close fitting rubber stopper, through which passed two glass tubes, as shown in the Plate Fig 9. The grape vine is fastened on the bent tube by means of a rubber tube, which is fastened over the vine at one end and closed at the other with a rubber stopper which contains a small hole through which the end of the bent tube passes. The sap passes from the vine through this tube into the bottle containing the mercury, presses down upon it and forces the mercury up the straight tube; The height of mercury is read by means of a scale graded to inches. The experiment was commenced april 17th, and observation were taken three times a day, "Morning, Noon, and Evening" until May 4th, after that

about twice a week, it made but little variation either way until the first of June, when it began to have a suction. When the experiment was completed June 9th the height of mercury in the bent tube was 7½ inches, in the straight tube 9 inches, the latter also contained 15 inches of water which rained in at the top. The following are the data from the observations.

		Height of mercury		
		Morning	Noon	Evening
April	17	10½ inches	11 inches	10 inches
"	18	13½ "	13½ "	13½ "
"	19	17 "	17 "	16½ "
"	20	13½ "	11 "	10½ "
"	21	7½ "	9¼ "	9 "
"	22	8 "	8 "	7¾ "
"	23	7½ "	8 "	8 "
"	24	9 "	10 "	9¼ "
"	25	9¼ "	10 "	10 "
"	26	12 "	12 "	11¾ "
"	27	14 "	13½ "	12 "
"	28	12 "	12½ "	12¼ "
"	29	12½ "	10½ "	9½ "
"	30	10 "	11 "	13 "
May	1	10½ "	10½ "	10½ "
"	2	11 "	11 "	10 "
"	3	11½ "	11¾ "	11½ "
"	4	11¾ "	12 "	11¼ "
"	5	11 "	11½ "	11½ "
"	6	11 "	11 "	10 "
"	7	10 "	9 "	9 "
"	8			
June	9			

		Temperature of Soil		
		Morning	Noon	Evening
April	26	48°	48°	49°
"	27	50°	51°	53°
"	28	53°	51½°	53°
"	29	53°	53°	54°
"	30	57°	57½°	58°
May	1	60°	60°	60°
"	2	58°	58°	59°
"	3	55°	55°	56°
"	4	55°	58°	57°
"	5	57°	58°	58°
"	6	57°	59°	58°
June	9	—	65°	—

		Temperature of air.		
		Morning	Noon	Evening
April	26	55°	56°	54°
"	27	54°	54°	53°
"	28	57°	58°	58°
"	29	54°	56°	56°
"	30	58°	59°	58°
May	1	60°	60°	60°
"	2	61°	62°	61°
"	3	60°	60°	60°
"	4	59°	61°	60°

To ascertain the amount of water given off by means of the leaves. I took first, a Geranium and a Tradescantia discolor. These were in good condition when removed from the pot: I placed them in tin cans packed well with soil so that they would be in as near a natural condition as possible. Then in order to keep the water from evaporating from the soil, this was covred with plaster of paris, and over this was poured some Linsed Oil which filled the small crevices and made an impervious surface. The plants were given sufficient water each day, through a small glass tube. This was plugged to prevent any evaporation by that means. The object of all this is to prevent any evaporation from the vessel in which the plant was situated, so that all evaporation was from the plant itself above the ground. The experiments were performed in the green house. The plants were carefully weighed in the morning and then again in the evening, the loss of wright give the amount of water

evaporated from the leaf surface during the day or the number of hours desired. The observations were made for a day and a night, the plants were weighed in the evening so as to establish the relation between day and night evaporation during the same twenty four hours. The condition of the weather was noted whether clear or cloudy; the temperature of the room was found by the Thermometer, and the mean temperature of the day was found by adding the results from the observations taken, and dividing this result by the number of observations. At the end of one week, I found that they lost more in the day time than by night: "the amount of evaporation in the latter was in some cases not perceptible by the scales, but in either case I never found an increase in weight." and that they transpired more rapidly upon a clear day than upon a cloudy one.

The following are the data from the two plants. "Geranium and Tradescantia discolor":

Results from a Geranium.

No 3 Experiments	Duration of Experiments	Loss by day Evaporation	Loss by night Evaporation	Entire Evaporation	Temperature	Weather	Place
	Am—Pm						
I.	8 — 5	90 Grains	30 Gr	120 Gr	57°	Cloudy	Green House
II.	" "	150 "	15 "	165 "	60°	Clear	
III.	" "	240 "	30 "	270 "	59°	Clear	
IV.	" "	150 "	30 "	180 "	60°	Clear	
V.	" "	240 "	30 "	270 "	65°	Clear	
VI.	" "	150 "	15 "	165 "	55°	Cloudy	
VII.	" "	210 "	0 "	210 "	65	Clear	

Results from Tradescandia discolor.

No 2 Experiments	Duration of Experiments	Loss by day Evaporation	Loss by night Evaporation	Entire Evaporation	Temperature	Weather	Place
	Am—Pm						
I	8 — 5	45 Grains	15 Gr	60 Gr	57°	Cloudy	Green House
II	" "	60 "	0 "	60 "	60°	Clear	
III	" "	45 "	0 "	45 "	59°	Cloudy	
IV	" "	0 "	15 "	15 "	60°	Clear	
V	" "	30 "	0 "	30 "	65°	Clear	
VI	" "	0 "	0 "	0 "	55°	Cloudy	
VII	" "	30 "	0 "	30 "	65°	Clear	

The geranium was 6 inches high, It contained 10 leaves 4 inches in diameter; 4 leaves 2 inches in diameter & 6 small shoots, making a leaf surface of about 75 sq. inches or doubling for both surfaces, which makes 150 sq. inches of leaf surface. The number of stomates upon the upper side are 2,000. to the sq. inch The number of stomates upon under side are 996 99 to the sq. inch. This plant gave off most water when the weather

was clear and when the thermometer stood the highest. The evaporation was very slight by night as compared with the day evaporation. The Tradescantia had a short stem about 2 inches long 1/4 of an inch thick; 4 leaves - 10 inches long, 1½ inches thick; 2 leaves 4 inches long, ½ inches thick at the base. The number of stomates to the sq-inch are 9969. This plant gave off very little water as as compared with the geranium, owing to the fact that the leaves were thicker and had fewer stomates to the sq-inch." in the latter."

This same experiment was performed with eight other plants, viz: Four Geraniums, Two Coleuses, Two Fuchias, One calla Lily. These were not watered from the time the experiment began until it ended, and to prevent evaporation they were placed in Tin cans, the dirt being covred with plaster of paris and that covred with bees-Wax. By this means there was no possible means for evaporation except through the leaves above the bees wax. The following are the data obtained from the plants mentioned above. See plate. Fig 1.

Results from Geranium No 1. No 2.

No of Experiment	Duration of Experiment	Loss by day Evaporation	Loss by night Evaporation	Total Loss	Temperature	Weather	Place	No of Experiment	Duration of Experiment	Loss by day Evaporation	Loss by night Evaporation	Total Loss	Temperature	Weather	Place
I	AM-PM 8 — 5	120 Grains	0 Grains	120 Gr	59°	Cloudy	Green House	I	AM-PM 8 — 5	120 Grains	0 Grains	120 Gr	59°	Cloudy	Green House
II	" "	60 "	15 "	75 "	60°	Cloudy		II	" "	60 "	30 "	90 "	60°	Cloudy	
III	" "	75 "	0 "	75 "	66°	Cloudy		III	" "	120 "	15 "	135 "	66°	Cloudy	
IV	" "	150 "	0 "	150 "	63°	Clear		IV	" "	180 "	30 "	210 "	63°	Clear	
V	" "	75 "	30 "	105 "	56	Cloudy		V	" "	195 "	30 "	225 "	56°	Clear	
VI	" "	60 "	0 "	60 "	55°	cloudy		VI	" "	105 "	15 "	120 "	55°	cloudy	
VII	" "	120 "	30 "	150 "	50	clear		VII	" "	160 "	30 "	190 "	50°	Clear	
VIII	" "	45 "	15 "	60 "	53	Clear		VIII	" "	75 "	15 "	90	53	Clear	

Nos 1 and 2. were common geraniums; herbaceous; the height of no 1. 4 in; weight fitted for experiment. 2 pounds 5¼ ounces; ~~evaporation~~ surface, 128 sq-in; No of stomates per square inch upon lower side 99673; upon upper side about 2000 to sq in; leaf surface to No 2. 164 sq. in; weight fitted for experiment 2 pounds 7 oz; No of leaves in each was 7; They were not watered during the experiment.

Results from Calla Lily.

No. of Experiment	Duration of Experiment	Loss by Day Evaporation	Loss by Night Evaporation	Total loss	Temperature	Weather	Place
I	a.m-p.m. 8 – 5	255 Grains	0 Grains	255 Gr	56°	Clear	Green House
II	" "	60 "	60 "	120 "	56°	Some Cloudy	
III	" "	45 "	45 "	90 "	56°	Cloudy	
IV	" "	135 "	0 "	135 "	53°	Clear	
V	" "	60 "	60 "	120 "	53°	Cloudy	
VI	" "	30 "	30 "	60 "	54°	Cloudy	
VII	" "	120	0 "	120 "	60°	Clear	
VIII	" "	30	0 "	30 "	57°	Cloudy	

Results from Fuschsia.

No. of Experiment	Duration of Experiment	Loss by Day Evaporation	Loss by Night Evaporation	Total Loss	Temperature	Weather	Place
I	a.m-p.m 8 – 5	120 Grains	0 Grains	120 Gr	56°	Clear	Green House
II	" "	90 "	0 "	90 "	56°	Some Cloudy	
III	" "	60 "	0 "	60 "	56°	Cloudy	
IV	" "	60 "	0 "	60 "	53°	Clear	
V	" "	15 "	15 "	30 "	53°	Cloudy	
VI	" "	60 "	0 "	60 "	54°	Cloudy	
VII	" "	60 "	0 "	60 "	60°	Clear	
VIII	" "	60	0 "	60 "	57°	Cloudy	

Calla Lily, height 15 inches; weight fitted for experiment 1 pound 11¾ oz; evaporating surface 120 square inches; No of stomates per sq-in, 60 424: upon the upper side 30 211; No of leaves, 3;

Fuschsia, height 12 inches; weight fitted for experiment, 2 pounds 1½ oz; evaporating surface 126, sq-inches; No of Stomates per Sq-in upon lower side 48378; No upon upper side 0; No of leaves 60. These were not watered during the Experiment.

Data from Coleus.

No of Experiment	Duration of Experiment	Loss by day-Evaporation	Loss by Night	Total Loss	Temperature	Weather	Place
I	One Week 8 – 6	180 Grains	0 Grains	180 Gr	56°	Clear	Cabin Porch
II	" "	240 "	0 "	240 "	56°	Cloudy	" "
III	" "	150 "	0 "	150 "	56°	Cloudy	" "
IV	" "	105 "	0 "	105 "	53°	Clear	" "
V	" "	60 "	0 "	60 "	53°	Cloudy	" "
VI	" "	75 "	0 "	75 "	54°	Cloudy	" "
VII	" "	120 "	0 "	120 "	60°	Clear	" "
VIII	" "	46 "	0 "	46 "	57	Cloudy	" "

Data from Fuchsia.

No of Experiment	Duration of Experiment	Loss by day Evaporation 8–12	12–6	Total	Loss by Night	Total Loss	Temperature	Weather	Place
I	Morning 8 m. Noon 12 m. Evening 6 m.	30 Gr	30 Gr	60 Gr	0 Grains	60 Gr	56°	Windy Clear Windy	Out of doors — — —
II	" " "	60 "	0 "	60 "	60 "	120 "	56°	Cloudy Windy	" " "
III	" " "	90 "	30 "	120 "	0 "	120 "	56°	Cloudy Windy	" " "
IV	" " "	30 "	30 "	60 "	15 "	90 "	53°	Clear calm	" " "
V	" " "	75 "	0 "	75 "	0 "	75 "	53°	Cloudy Windy	" " "
VI	" " "	60 "	30 "	90 "	15 "	120 "	54°	Cloudy calm	" " "
VII	" " "	45 "	30 "	75 "	15 "	105 "	60°	Clear calm	" " "
VIII	" " "	15 "	0 "	15 "	0 "	15 "	57°	Cloudy	" " "

Coleus. height 12 inches; wright fitted for experiment 2 pound 0 3/4 oz; evaporating surface 160 sq-inches; No of stomates upon lower side per sq-inch, 99693; upon upper side 0; No of leavs 90. The fuchsia is the same one experimented with on pag 14; after an elapse of 8 weeks without watering the experiment was repeated out of doors, it gradualy gave off less water until it withered, then it ceased to transpire.

Data from Geranium.

No. of Experiment	Duration of Experiment			Loss by day Evaporation			Loss by Night	Total Loss	Temperature	Weather	Place
	Morn am 8	noon m 12	Eve pm 6	8-12	12-6	Total					
I				90 Gr	0 Gr	90 Gr	60 Grains	240 Grains	63°	Cloudy Windy	Out door
II	"	"	"	300 "	120 "	420 "	60 "	480 "	60°	Windy Clear	"
III	"	"	"	180 "	60 "	240 "	0 "	240 "	65°	Windy Clear	"
IV	"	"	"	150 "	15 "	165 "	15 "	180 "	62°	Windy Clear	"
V	"	"	"	90 "	0 "	90 "	0 "	180 "	70°	Windy Clear	"
VI	"	"	"	90 "	30 "	120 "	15 "	135 "	70°	calm Clear	"
VII	"	"	"	45 "	15 "	60 "	15 "	75 "	75°	Windy cloudy	"
VIII*	"	"	"	210 "	180 "	390 "	15 "	405 "	69°	Windy Clear	"
IX*	"	"	"	45 "	15 "	60 "	0 "	60 "	68°	Calm cloudy	in door
X*	"	"	"	15 "	0 "	15 "	0 "	15 "	71°	calm cloudy	"

Data from Coleus.

No. of Experiment	Duration of Experiment			Loss by day Evaporation			Loss by Night	Total Loss	Temperature	Weather	Place
	Morn am 8	Noon m 12	Evening pm 6	8-12	12-6	Total					
I				60 Gr	30 Gr	90 Gr	60 Gr	150 Gr	63°	Windy Cloudy	Out door
II	"	"	"	300 "	90 "	390 "	30 "	420 "	60°	Windy Clear	"
III	"	"	"	120 "	15 "	135 "	0 "	135 "	65°	Windy Clear	"
IV	"	"	"	150 "	90 "	240 "	0 "	240 "	62°	Windy clear	"
V	"	"	"	60 "	0 "	60 "	0 "	60 "	70°	Windy Clear	"
VI	"	"	"	15 "	15 "	30 "	0 "	30 "	70°	Calm Clear	"
VII	"	"	"	30 "	15 "	45 "	30 "	75 "	75°	Windy Clear	"
VIII	"	"	"	30 "	30 "	60 "	0	60 "	69°	calm Cloudy	"
IX	"	"	"	0 "	0 "	0 "	0	0 "	68°	Calm Cloudy	in door
X	"	"	"	0 "	0 "	0 "	0	0 "	71°	calm cloudy	"

Geranium, height, 8 inches; weight fitted for experiment 2 pounds $2\frac{15}{16}$ oz; No of leaves 26; leaf surface 180 sq inches. This plant was left out of doors during the experiment, and was not watered until the seventh day, the next day it gave off six and one half times more water than the day preceding. Before watering it gradualy transpired less

each day. Coleus, height 15 inches; weight fitted for experiment 2 pounds. 9/16 oz; leaf surface 180 sq-in. This plant was in a healthy condition when the experiment was commenced, at the end of the fifth day the leaves began to wither, upon the eight day they were all off except a few small shoots. It was found after that it ceased to transpire.

Conclusion.

In conclusion, I find that the difference of evaporation between twelve hours day time and night time was in the ratio of 7 to 1; that is the leaves transpire seven times more water during the day time than the night time. In the last three plates they show that more water is given off in the four noon, than the after noon. The rate of evaporation varies greatly on account of the nature of the leaf surface, as may be seen by comparing the Tradescantia discolor with the other plants. The sun's rays stand first in importance in effecting evaporation. Thus by noticing those that were performed in Green house

where the temperature remained about the same on a clear day as upon a cloudy day, they gave off from twice to three times as much more water in favor of the former. They transpired more rapidly out doors than in doors; and more rapidly upon a windy day than a calm day. They also transpired more rapidly when watered each day, than when not water, as is proven in the experiment with the Geraniums on pages 10 and 15, as compared with the others. The latter gradualy gave off less water until they withered, then ceased to transpire.

The following table compares the different plants which were used in the experiments; gives the average amount of evaporation during the day and night; the leaf surface of each; the duration of the experiment; average temperature; the condition of the weather wheather clear or cloudy; the weights; and also the amount of water given off from each square inch of leaf surface during the day times.

Nos of Plants.	Names of plants	Average amt of Evaporation day	Night	Duration of Experiment	Weight	Amt transpired per Sq in. surface per day.	average Temperature	Weather Clear	Cloudy	Leaf Surface
I.	Geranium	175 2/7 Grains	24 2/7 Grains	9 hours day	1 pound 8 oz	1 1/6 Grains	60 1/7°	3 days	4 days	1558 Sq in
II	Geranium	93 5/8 "	11 1/8 "	9 "	2 " 5 1/4 "	47/64 "	55 3/5°	3 "	5 "	128 " "
III	Geranium	122 "	20 5/8 "	9 "	2 " 7 "	61/82 "	55 7/8°	3 "	5 "	164 " "
IV	Fuchsia	69 5/8 "	2 "	9 "	2 " 1 1/2 "	11/21 "	56°	5 "	3 "	126 " "
V	Calla Lily	62 "	20 5/8 "	9 "	1 " 11 1/4 "	1/2 "	56°	5 "	3 "	124 " "
VI	Coleus	119 3/4 "	0 "	9 "	2 " 0 3/4 "	3/4 "	56°	5 "	3 "	160 " "
VII	Tradescantia	30 "	4 2/7 "	9 "	3 " 9 3/16 "	16/68 "	60 1/7°	3 "	4 "	136 " "
VIII	Fuchsia	67 "	13 5/8 "	12 "	2 " 4 1/4 "	67/126 "	69°	5 "	3 "	126 " "
IX	Coleus	124 1/4 "	15 5/8 "	12 "	2 " 9 11/16 "	31/45 "	69°	5 "	3 "	180 " "
X	Geranium	145 "	18 "	12 "	2 " 2 15/16 "	27/36 "	69°	5 "	3 "	180 " "

Nos 1 and 7, were performed in the Green house and watered regular each day. Nos 2. 3 4. 5. 6, were also performed in the Green house but not watered during the experiment, The first two "2 & 3" were used as tests to determine which would transpire more rapidly. With Nos which is the same

plant as no 6, the experiment was repeated out of doors without being watered. no 10 was also performed out of doors until the eight day then the experiment was performed in the house.

In these experiments I never found any increase in wright.

Finis.

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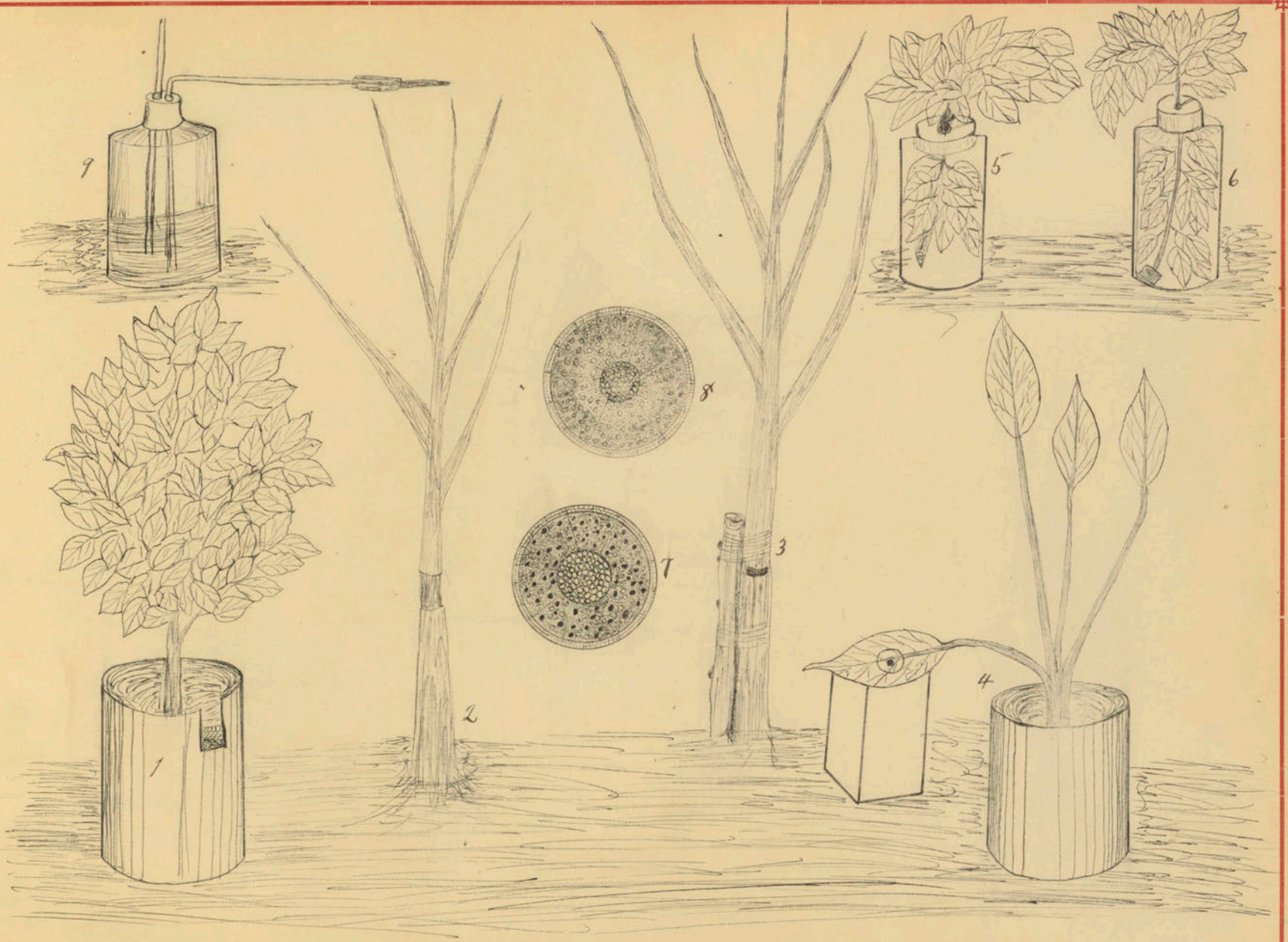
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